THOR (Thermal High-voltage Ocean-penetrator Research platform)

Completed Technology Project (2018 - 2022)

Project Introduction

Robotic exploration and life search on ocean worlds requires the ability to access habitable ocean environments concealed beneath thick ice crusts. Additionally, an instrument suite is required to perform the complicated task of autonomous life detection. We propose to address these technological and operational requirements for ocean world access with THOR, a robust cryobot capable of rapid (10 m/hr), deep (500+ m) subglacial access that carries an onboard science payload optimized for environmental characterization and life detection. THOR will be deployed at the eastern Skaftafell subglacial lake in Vatnajokull, Iceland where it will penetrate the thick ice cover of the lake. Successful fielding of THOR will mark the first cryobot descent into a subglacial lake, thus enabling unique investigations of both the lake's geomicrobiology and of CONOPS strategies for a cryobot's entry into, and descent through, a subglacial body of water. The THOR team leverages successful work from the VALKYRIE and SPINDLE projects and offers fidelity to PSTAR in the areas of Science, Science Operations, and Technology. a) Science: Investigations of the eastern Skaftafell lake will center around detecting and characterizing microorganisms in the water column and volcanic vents to decipher the contribution of chemical energy liberated from geothermal vs. glaciological processes. To aid these investigations, THOR will carry a suite of instruments chosen to characterize the environment of the ice and subglacial lake, with a specific focus on life-detection strategies. Onboard instruments will include a fluorescence spectrometer, a holographic microscope capable of imaging prokaryotic cells, an inorganic chemistry measurement suite, a transmissometer / backscattering sensor, and a water sampler. A nanopore DNA sequencer will be used on-site to analyze water samples acquired by THOR. Comparative analysis will utilize water column and vent material samples, which will be returned to the surface and analyzed. b) Science Operations: At Skaftafell the THOR cryobot will penetrate a 300 m thick glacier and enter the subglacial lake in the volcano's crater. Upon reaching the ice-water interface, the cryobot will transition into an instrument sonde and spool itself to the lake floor while sampling and analyzing the water column. This penetrator-to-sonde strategy is a new step-wise approach to the initial exploration of an alien ocean. As the vehicle descends input from the sensor suite will govern decision-to-collect behaviors to trigger processes such as water sampling. The system will be retrieved after each mission and we anticipate completing several descents in each of two field seasons. Exploring methods which could be used to detect extant life on ocean worlds is of high importance. To that end, we will assess how well and in what ways the suite of instruments function together to determine whether life is present and at what quantities. Conventional limnological and microbiological techniques using water samples acquired by THOR will be used to evaluate autonomous sampling decisions. c) Technology: The cryobot design will use a closed-cycle hot water drill approach wherein the water is heated in a novel way: high voltage is applied across a flowing column of water, which serves as the resistive element in an electro-resistive heater. Energy transfer from the

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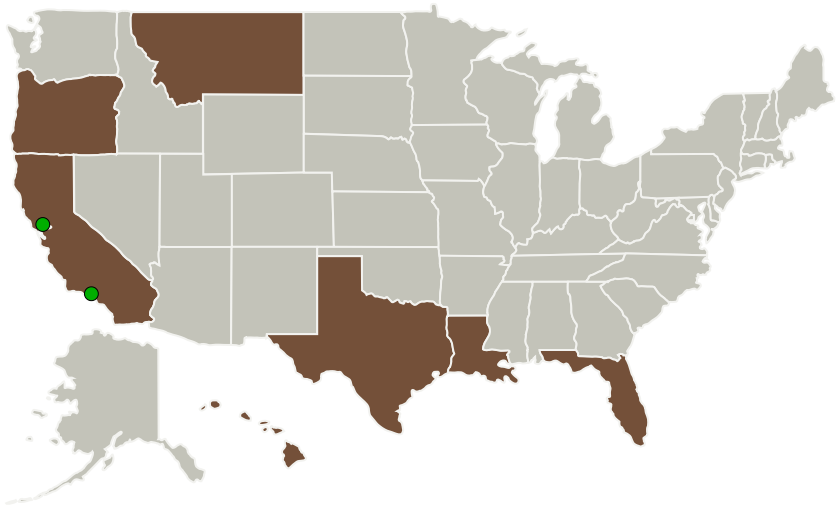
electrical source to the water is instantaneous and occurs at 100% efficiency. Direct high voltage heating, combined with new insulation technology, makes possible a compact cryobot that is capable of rapid descent and deep subglacial access with a small field-logistics footprint. Given its simplicity, the cryobot will be inexpensive, easily deployable, and field serviceable. The THOR platform will enable unprecedented access to subglacial environments, making it an ideal payload delivery system for ocean worlds technology development and analog research in this PSTAR project and beyond.

Anticipated Benefits

Developing Instrument or spacecraft technology to improve measurements for future planetary science missions.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Lead Organization:

Stone Aerospace, Inc.

Responsible Program:

Planetary Science and Technology Through Analog Research

Project Management

Program Director:

Carolyn R Mercer

Program Manager:

Sarah K Noble

Principal Investigator:

William C Stone

Co-Investigators:

Kathryn F Bywaters
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Peter T Doran
Nathan E Bramall
Jan P Amend
Christopher P Mckay
Eric Gaidos
Mark Skidmore
Jay L Nadeau
William C Stone
Kevin P Hand

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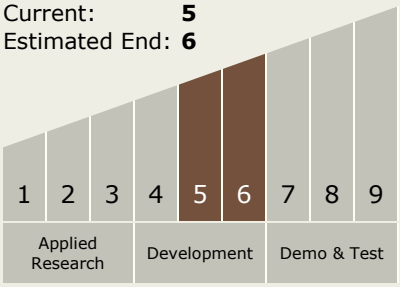
Organizations Performing Work	Role	Type	Location
Stone Aerospace, Inc.	Lead Organization	Industry	Del Valle, Texas
Ames Research Center(ARC)	Supporting Organization	NASA Center	Moffett Field, California
Jet Propulsion Laboratory(JPL)	Supporting Organization	NASA Center	Pasadena, California
Leiden Measurement Technology, LLC	Supporting Organization	Industry	Sunnyvale, California
Louisiana State University and Agricultural & Mechanical College(LSU)	Supporting Organization	Academia	Baton Rouge, Louisiana
Montana State University - Bozeman	Supporting Organization	Academia	Bozeman, Montana
Portland State University	Supporting Organization	Academia Asian American Native American Pacific Islander (AANAPISI)	Portland, Oregon
University of Florida	Supporting Organization	Academia	Gainesville, Florida
University of Hawaii Maui College	Supporting Organization	Academia Alaska Native and Native Hawaiian Serving Institutions (ANNH), Asian American Native American Pacific Islander (AANAPISI)	Kahului, Hawaii

Technology Maturity (TRL)

Start: **5**
Current: **5**
Estimated End: **6**



Technology Areas

Primary:

- TX04 Robotic Systems
  - TX04.2 Mobility
    - TX04.2.1 Below-Surface Mobility

Target Destination

Others Inside the Solar System

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Primary U.S. Work Locations	
California	Florida
Hawaii	Louisiana
Montana	Oregon
Texas	